# Controller Evaluation of CPDLC Services Implemented on the Display System Replacement (DSR) Workstation:

## Study 1 -- Initial Assessment of Services Transitioned From the PVD and Design Development for Additional Services

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16. Abstract

This report presents the results of the first of a series of studies being conducted by ACT-350 at the Federal Aviation Administration (FAA) William J. Hughes Technical Center to evaluate and refine the controller human computer interface (HCI), air traffic procedures, and training for Controller Pilot Data Link Communications (CPDLC). The objectives of this study were to: (1) evaluate the baseline Display System Replacement (DSR) HCI and functionality for the four CPDLC Build I (CPDLC I) services; (2) assess initial concepts for implementing the route assignment and downlink services needed for CPDLC Build IA (CPDLC IA); and (3) examine alternatives for Full Data Block (FDB) Data Link symbols available in DSR.

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# EXECUTIVE SUMMARY

This report presents the results of the first of a series of studies being conducted by ACT-350 at the Federal Aviation Administration (FAA) William J. Hughes Technical Center to evaluate and refine the controller human computer interface (HCI), air traffic procedures, and training for Controller-Pilot Data Link Communications (CPDLC). The objectives of this study were to: (1) evaluate the baseline Display System Replacement (DSR) HCI and functionality for the four CPDLC Build I (CPDLC I) services; (2) assess initial concepts for implementing the route assignment and downlink services needed for CPDLC Build IA (CPDLC IA); and (3) examine alternatives for Full Data Block (FDB) Data Link symbols available in DSR.

Eight en route Air Traffic Control Specialists (ATCS) participated in the study. The controllers received classroom training and hands-on practice with the DSR and the CPDLC HCI in the high-fidelity air traffic control (ATC) simulation laboratory at the Technical Center. Following 4 hours of dynamic simulation experience with CPDLC I, the controllers completed individual design reviews, and participated in a group debriefing on the HCI and functionality provided by the baseline CPDLC I services. Finally, the controllers were exposed to baseline designs for the downlink and route assignment services, exercised the services in the laboratory, and made recommendations for design changes in a group debriefing.

The group's design recommendations were divided into two categories. The first category included design changes that were judged as essential to the successful deployment of CPDLC I during the limited key site implementation. The second included modifications and enhancements that will be mandatory for inclusion in CPDLC IA and future system builds.

The following were design improvements considered essential for CPDLC I:

     a. Status list message entries that are in a non-normal state (e.g., FAI, UNA, TIM) must be visually emphasized to improve the alerting value of the state indicators.

     b. The Data Link eligibility symbol in the FDB should be changed to a filled diamond, and the symbol used to indicate an ongoing transfer of communication should be changed to a lightning bolt.

     c. The Data Link Settings HCI should be modified to permit more efficient and accurate controller interaction.

d. The locations of two Data Link keyboard keys should be changed to improve accessibility.

Additional design changes strongly recommended for future system builds included converting Data Link lists to DSR views and providing improved functionality and a dedicated HCI to the Radar Associate Controller (D-Side). Specific suggestions for implementing the recommended modifications to CPDLC I, and future system builds are presented in the results section of this report.

The design generation exercise for the CPDLC IA route assignment service and for displaying and processing downlinked altitude requests yielded a number of recommended modifications to the baseline designs. These changes will be incorporated into the Data Link test bed and evaluated in future simulation studies.

# 1. INTRODUCTION.

## 1.1 PURPOSE.

This document describes the findings of the first of a series of studies that will be conducted by ACT-350 at the Federal Aviation Administration (FAA) William J. Hughes Technical Center to evaluate and refine the controller human computer interface (HCI), air traffic procedures and training for the first build of Controller-Pilot Data Link Communications (CPDLC). The study described here is in accordance with the recommendations and goals presented in the CPDLC Roadmap for Human Factors Activities (Data Link Human Factors Working Group, 1998).

## 1.2 CPDLC IMPLEMENTATION PLANS.

In cooperation with industry, the FAA has adopted a revised plan for implementing CPDLC in en route airspace. The new implementation path bypasses the original plan to conduct an early operational trial of CPDLC using the ARINC Communications Addressing and Reporting System (ACARS) subnetwork. Instead, development and testing will be focused on an Aeronautical Telecommunications Network (ATN)- compliant implementation using the VDL Mode 2 subnetwork which will be capable of effectively supporting a broad range of air traffic control (ATC) communications services.

The FAA's goal is to field a full CPDLC application by 2005. This will be accomplished under a phased approach. The initial phase (CPDLC I) will introduce the messages required to provide four non-time-critical services: Transfer of Communication (TC), Initial Contact (IC), Altimeter Setting (AS), and a free text menu capability (MT) used to send informational messages to the flight deck. CPDLC I will be fielded at a key site (Miami Air Route Traffic Control Center (ARTCC)) in June 2002.

The plan calls for deployment of the next CPDLC build (CPDLC IA) beginning with a key site implementation in June 2003 followed by national implementation within the next several months. CPDLC IA will expand the message set to support speed, heading, altitude, and route assignments. In addition, an initial capability to accommodate downlinked altitude requests will be included.

In December 2004, key site implementation of CPDLC II will be initiated with national deployment commencing thereafter. This system build will constitute a mature version of CPDLC capable of fully supporting ATC operations for the next several years. The message set will support multipart clearances, report instructions, and an enhanced capability for flight crews to downlink requests

and responses to ATC queries. CPDLC III is a far-term (2010+) version of the system which will further refine air-ground messaging and upgrade to a more robust communications subnetwork.

## 1.3   CPDLC HUMAN FACTORS REQUIREMENTS.

Successful achievement of the FAA's goals in each of the implementation phases outlined above will depend on the resolution of outstanding human factors issues associated with CPDLC. Focused ground side and flight deck research efforts will be needed to define HCI requirements, develop supporting procedures, and insure that users are provided with effective training programs. Additional high-fidelity simulation testing with both pilots and controllers in-the-loop will be required to validate the end-to-end usability and functionality of the system.

The rapid progression of the implementation schedule demands that the human factors issues associated with each phase of CPDLC be addressed as early as possible in the development and testing process in order to have a meaningful effect on the equipment, software, and procedures that reach the field.

## 1.4   NEAR-TERM CONTROLLER HUMAN FACTORS RESEARCH PLANS.

During 1999, ACT-350 of the Technical Center intends to conduct a series of studies to address groundside, ATC human factors issues associated with CPDLC I and IA. The overriding goals of these studies will be to: (1) resolve the controller human factors issues associated with CPDLC I prior to operational test (OT) in 2000; (2) insure that HCI and procedural decisions made for CPDLC I are compatible with the requirements for future system builds with larger message sets; and (3) provide HCI and service design criteria for CPDLC IA with sufficient lead time to effectively impact the software development cycle.

These studies will take place concurrently with corresponding flight deck test and development activities and will lead directly to joint controller and pilot in-the-loop testing.

The near-term ground side research will build upon over 10 years of prior work conducted by ACT-350 at the Technical Center. Among other products, this research generated a set of thoroughly tested and validated CPDLC services for the plan view display (PVD) workstation. The set included the four services included in CPDLC I (TC, IC, MT, and AS) and three of the services added by CPDLC IA (altitude, speed, and heading assignments).

Most recently, ACT-350 conducted a design review intended to obtain preliminary controller inputs to the HCI for transitioning the CPDLC services previously implemented on the PVD to the Display System Replacement (DSR)

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workstation (Darby, 1998). Participants including controllers from the Air Traffic Data Link Validation Team (ATDLVT), DSR team, and National Air Traffic Controllers Association (NATCA) examined the HCI design plans and provided recommendations for DSR CPDLC key assignments, full data block (FDB) symbology, display parameters, and the functionality of the IC service. Based on these findings, ACT-350 proceeded to incorporate the DSR laboratory at the Technical Center into the Data Link test bed facilities and to implement the preliminary designs for CPDLC HCI and functionality in the operational equipment.

This document describes the findings of the first of three studies that will be conducted to refine the controller HCI for CPDLC through Build IA, validate proposed CPDLC procedures, and assess controller training techniques. The primary purpose of this first study was to provide an initial review of the CPDLC I services as implemented on the DSR, and to obtain controller input on the design of the route assignment and downlink services needed to complete the CPDLC IA package.

## 2.   OBJECTIVES.

The specific objectives of this study were to:

   a.   Evaluate the acceptability of initial DSR HCI and functionality for CPDLC I services transferred from the PVD.

   b.   Assess initial concepts for implementing the route assignment service and for handling pilot downlink messages.

   c.   Examine DSR symbology alternatives for FDB session/eligibility symbols.

## 3.   TEST CONDUCT.

### 3.1   TEST PARTICIPANTS.

The participants in this study were eight ATC Specialists. Four of the controllers were en route members of the ATDLVT who have subject matter expertise on ATC Data Link communications. The ATDLVT was established to provide user input during the development of the CPDLC message services and PVD HCI design. Each of the controllers assigned to the team participated extensively in the design process and has many hours of experience in using CPDLC during high fidelity simulation studies.

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Two additional controllers were drawn from an air traffic team that had participated in the DSR development process. These controllers are familiar with the DSR HCI and associated input and display conventions.

The remaining two controllers were NATCA representatives who are participating in the CPDLC implementation process and a Supervisory ATC Specialist from the Miami ARTCC (CPDLC I key site).

Informed consent to participate in the exercise was obtained from each participant upon arrival at the Technical Center. The consent form is contained in appendix A of this plan.

## 3.2  TEST FACILITIES AND AIRSPACE.

The study took place at the Technical Center facilities used to provide high-fidelity simulations of ATC operations. The DSR laboratory houses the en route controller workstations that were used for the simulation exercises conducted during this study. This facility is configured to duplicate a field installation, providing direct connection to the Host Computer System (HCS). The functions of the Data Link Applications Processor (DLAP) were emulated by a Sun workstation. The Sun workstation also inserted time delays to simulate system transaction and pilot response delays to uplinked CPDLC messages. Transmission delays varied over the upper portion of the range specified by the CPDLC I specification. The one-way transmission delays were randomly selected from a rectangular distribution ranging from 6 to 11 seconds. Maximum pilot delays were determined by actual pseudopilot response times. The minimum response delay permitted by the system was 5 seconds.

Pilot functions were provided using the Dynamic Simulation (DYSIM) training capability of the Host. Under the DYSIM mode of operation, pseudopilots working from DSR consoles had the ability to receive and send Data Link messages, and to make inputs to realistically maneuver aircraft in response to controller clearances.

In order to minimize airspace familiarization and training requirements, four contiguous sectors selected from the ZCY airspace were used for this study. ZCY is a generic airspace adaptation used for technical testing in the DSR/HCS system. Standardized air traffic scenarios previously developed for ZCY were employed to present controllers with opportunities to exercise the CPDLC messaging capabilities in the context of dynamic ATC activity.

## 3.3  TEST PROCEDURES.

The study was conducted over a period of 3 days.  Upon arrival at the Technical Center, the participants received an overview briefing describing the objectives of the study, the activities to be conducted, and their responsibilities in assessing CPDLC on the DSR.

### 3.3.1  DSR Familiarization.

The study began with a classroom session that was used to familiarize the controllers with the DSR HCI.  The intent of this effort was to provide the participants with knowledge of the display and input conventions used in DSR. Emphasis was placed on the differences between the PVD and DSR controller interaction requirements.

The participants viewed selected lessons from the DSR Computer-Based Instruction (CBI) curriculum in a group session.  These interactive lessons were presented using a personal computer system combined with the DSR trackball and keyboard.  The lessons were selected to focus on key elements of the display and input conventions of the DSR.

The controllers performed DYSIM hands-on HCI activities in the DSR laboratory.  The activities were derived from training scenarios developed for DSR which require controllers to exercise all major DSR interaction skills.

### 3.1.2  CPDLC HCI Familiarization.

DSR training activities were followed by a classroom training session to familiarize the controllers with the baseline DSR HCI for the CPDLC services originally developed for the Host/PVD system.  The session presented the proposed DSR keyboard inputs and displays associated with sending TC, MT, and AS messages, monitoring Data Link transactions including IC errors, and adjusting Data Link settings.

The classroom session was followed by two practice periods in the DSR laboratory.  The first practice period presented the controllers with a low traffic scenario.  The controllers were given a checklist of CPDLC tasks to perform while controlling traffic.  These tasks required the controllers to exercise all of the Data Link settings controls, send the transfer of communications message using both the manual and automatic modes, observe the FDB displays of transaction status and equipage/eligibility, and experience failure displays including "time-out" and IC altitude mismatches.   Each pair of controllers alternated between the positions at their sector in order to provide them with experience in the Radar and Data controller CPLDC inputs.

The first practice period was followed by a brief discussion session to answer any open questions about the baseline CPDLC HCI and the rationale that guided its design. In the second practice session, traffic was increased to provide the controllers with a more realistic experience in using CPDLC under moderately high workload conditions. As in the first session, controllers rotated between the Radar and Data positions. In addition, they were encouraged to experiment with alternative methods of sharing CPDLC communications duties between the two positions. During the last hour of the 2-hour session, alternative options for two of the Data Link FDB symbols were exchanged for the originals in order to permit the controllers to examine them.

### 3.1.3 CPDLC HCI and Functionality Design Review.

A detailed evaluation of the CPDLC design followed the second practice session. Each controller performed an independent evaluation by completing the questionnaire items contained in a design review booklet (appendix B). The booklet structured the controller evaluations around six primary topics: (1) Data Link Keys; (2) Data Link FDB and Status List Displays; (3) TC; (4) MT; (5) IC; and (6) AS.

The displays and inputs for each service were presented for individual evaluation using descriptive text. In each case, the controller was asked to provide an overall evaluation of each service design, and to record any recommended or required design modifications. They also were asked several specific questions regarding the adequacy of displays and alerts, the workload associated with data inputs for each service and the functional compatibility of the services with existing ATC tasks and procedures.

The questionnaire was also used to solicit controller opinions regarding outstanding CPDLC design issues. The confusability and acceptability of the alternative symbol set available in the DSR were rated as potential replacements for the "hourglass" used in the FDB to indicate Data Link equipage and eligibility, and the pound sign used to indicate the "sent" status of TC messages.

### 3.1.4 Structured Debriefing.

The individual design review was followed by a structured group debriefing and discussion session. The session was used to perform an item-by-item review of the controllers' responses to the design review questions and ratings. The primary emphasis of the debriefing was to identify and resolve any disagreements regarding the suitability and acceptability of the CPDLC I HCI design. In addition, the debriefing was used to identify improvements that could be omitted from CPDLC I, but were desirable, or mandatory, for future system builds.

The group discussion was documented in notes recorded by test personnel and on an audiotape record for reference during data analysis and report preparation.

### 3.1.5 Design Generation for Route Assignment and Downlink.

CPDLC IA will include two services that have not been previously developed and tested on the PVD workstation (route assignment and pilot downlink). For this reason, the controllers participated in a structured group discussion focused on obtaining a preliminary design (or set of design options) for these services that can be implemented in the test bed and evaluated in a future study.

The controllers were first presented with baseline designs for the services in a briefing supported by illustrative slides. Discussion topics included options for route assignment data entry and display of message content, as well as options for notifying the controller of a pilot downlink, displaying the message, and responding.

The controllers returned to the DSR laboratory to observe and interact with the baseline designs during an ATC scenario. Finally, the group participated in a critique of the baseline designs.

The results of the design generation exercise were recorded in test personnel notes. In addition, an audiotape of the discussion was recorded for reference during the preparation of documentation for preliminary designs.

### 4.    RESULTS.

### 4.1   CPDLC I HCI AND FUNCTIONALITY.

The findings presented below are a synthesis of the inputs that were obtained from the independently written controller design reviews and the structured group debriefing. It should be noted that the design review and debriefing focused on requirements for CPDLC I. Although several suggested modifications were considered, the group indicated that the majority of them could be deferred to CPDLC IA. The distinction between changes essential for CPDLC I and those that must be included in CPDLC IA is maintained in the following description of the findings.

### 4.1.1   Data Link Keys.

The locations of the four DSR keys that were evaluated during this study are shown in figure 1 below:
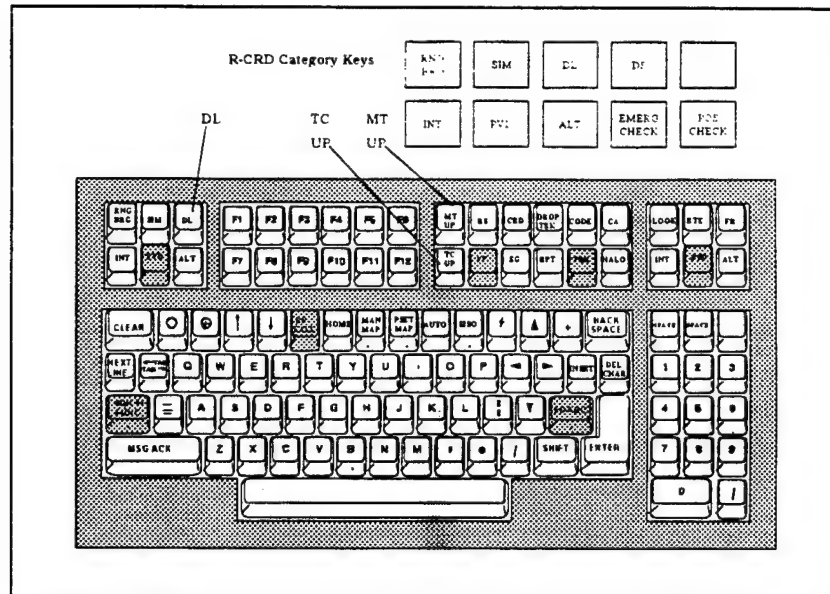
FIGURE 1. DSR DATA LINK KEYBOARD

The consensus of the group was that, for CPDLC I, the *MT UP* and *TC UP* keys should be relocated to the far right of the bank of 12 hard-labeled function keys in which they were positioned for testing. The controllers noted that this location was preferable because it would permit rapid access to the keys when making entries on the numeric keypad and when using the routinely employed function keys located in the six-key bank to the right of the keyboard.

A majority of the participants agreed that the Data Link key labels were meaningful and not susceptible to confusion with other key designations. While color coding of the key caps to enhance distinctiveness was discussed during the debriefing, it was noted that two colors had already been added to the DSR key caps, and that proliferation of the practice may diminish the value of color as an aid to key identification.

In a general comment, several controllers indicated that, in some cases, there were inconsistencies among abbreviations used to refer to Data Link functions and services in displays, labels, and two-letter Host commands (e.g., the use of both TC and TOC to refer to transfer of communication.) It was recognized that some of these might be impossible to modify because a Host command may already be in use by pre-existing functions. However, the group suggested that an effort be made to improve the consistency of representations used in displays and labels in order to reduce training time and minimize memory demands.

Finally, when asked whether it would be acceptable to eliminate the Data Link keys and require controllers to access their functions using only the optional

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two-letter Host commands, the participants unanimously agreed that the keys were required to reduce workload and to facilitate rapid Data Link entries.

<u>4.1.2  Data Link Settings</u>.

The evaluated design for adjusting Data Link settings used a pick area category key (*DS*) which displayed available options in the text area of the R-CRD.  These options included transfer of communication mode (man/auto), menu text and status lists on/off, and various menu text and status list filtering options.  One of the selectable functions (sector settings) displayed the current selection for each of the options.  During the adjustable duration of the sector settings display, changes could be made and displayed dynamically by composing messages using two-letter Host commands.

The controllers found the Data Link settings display and functionality non-intuitive and awkward to use.  When making the setting changes by pressing *DS*, selecting one of the functions, and making the appropriate entries, no feedback was provided to indicate the results of the input.  To obtain this feedback, the controller had to press *DS* again, and select sector settings.  Alternatively, if the controllers changed the settings by accessing the sector settings display and making the adjustments while the display was in view, they were required to recall the entire command sequence including the two-letter Host message.

As a group, the controllers argued for a data link settings display that would (1) clearly identify each function, (2) display its current setting, (3) indicate the available options for the setting, (4) cue the inputs needed to make a change, and (5) provide immediate feedback regarding the change that has been made.

The controllers concurred that the following redesign of the Data Link settings function should be implemented for CPDLC I to provide a more usable system:

> a.  The default (hot) function under the *DS* key should be changed to the current sector settings.

> b.  All other functions currently displayed under *DS* should be removed.

> c.  Typing *DS* Enter or "SN" Enter will then evoke the display shown on the following page in the R-CRD Text Area.  This display is a modification of the current sector settings display.

As before, the display will remain in the text area for an adjustable time parameter, during which the controller can make changes using the two-letter commands shown in the list.  The SVCS ON display is controlled by the facility and cannot be changed at the sector.  Because of display space limitations, MT

SUPR/RECALL will not show the menu item referents that are suppressed. However, inputs made to suppress or recall items will be reflected in the menu text list on the situation display. Changes to the other options will be immediately displayed to the controller (e.g., OFF/ON or in the case of SL SVCS SUPR and SL STATES SUPR by a highlighted display of those services/states abbreviations that are not suppressed.) In the example shown in the illustration, AS messages and all messages in the SNT and ROG states are suppressed from the status list.

The two-letter host message and the settings options (e.g., ON, OFF, IC, AS, WIL) are presented in the display to support composition of the inputs needed to modify each setting. In addition, the order in which the settings are listed on the display is modified from the original sector settings display in order to provide more logical groupings, see figure 2.

| T | CRD | | | KEYS | CODE |
|---|---|---|---|---|---|
| RNG BRG | SIM | DL | | DS | |
| INT | PVD | ALT | | EMERG CHECK | POS CHECK |

```
              DATA LINK SETTINGS
SVCS ON  IC AT MT TC
SECTOR                        XX     ON
AUTO TC                       AT     OFF
MT DISPLAY                    MT     ON
MT SUPR/RECALL                MS

SL DISPLAY                    SL     ON
SL SVCS SUPR                  SV
    IC  AS   TC   MT
SL STATES SUPR
    WIL SNT ROG
```

| RA | MWL |
|---|---|
| - RESPONSE AREA - (4 LINES) ACCEPTS/READOUTS | |

| MC | READY |
|---|---|
| - MESSAGE COMPOSITION AREA - (6 LINES) | |

- PREVIEW AREA -
(2 LINES)

- FEEDBACK AREA -
(4 LINES)
FOR ERROR MESSAGES

FIGURE 2. DSR R-CRD DATA LINK SETTINGS

Several controllers indicated that providing for trackball access to the sector settings would further enhance the design described above. Specifically, they suggested that controllers be given the ability to toggle among the setting options by trackball selection of the appropriate list item.

For future CPDLC builds, the DSR conventions for display and controller interaction dictate that the entire data link settings functionality should be implemented in the Display Control (DC) View. The DC view uses a matrix of pick keys to setup the sector (brightness, font, map size, etc.) The pick keys provide selection options and show current state. The controllers recommended that for CPDLC IA, the DC view should be explored as a possibility for implementing all Data Link settings. Additionally, Data Link settings should be incorporated with the forthcoming implementation of preference options that will automatically adjust all sector settings for DSR according to individual controller default selections.

### 4.1.3 FDB Symbols.

After observing the FDB symbol options that were presented during the CPDLC DYSIM exercises, a clear majority of the controllers indicated that changes should be made for CPDLC I. Seven of the eight controllers rated the filled diamond as the best option for indicating that the aircraft is equipped, has an active session, and that the observing controller is eligible to communicate with the aircraft. The eighth controller rated the filled diamond as an acceptable option, and the original hourglass symbol as an unacceptable option. Identical ratings were obtained for the use of the lightning bolt symbol as a replacement for the pound sign to indicate that a transfer of communication transaction is in progress.

The filled diamond was judged to be more meaningful than the hourglass, as well as more consistent with the open diamond originally used to indicate equipage/active session without eligibility. The lightning bolt was judged to be an improvement because it was seen as an inherently meaningful indication of an ongoing transaction, and because the original pound sign was confusable with the coast track symbol.

Several of the controllers noted that the filled diamond and lightning bolt symbols were smaller than the alphanumeric font used in the FDB. They indicated that this could present problems when the controller selects small font sizes, and that an effort should be made to increase the height of the Data Link symbols.

### 4.1.4 Status List Alerts.

The group concurred that the abbreviations used to indicate transaction status were clear and easy to understand. However, the controllers were unanimous in their judgment that the "abnormal" status indications (NEG, UNA, FAI, ERR, and TIM) were not sufficiently obvious to reliably alert the controller and prompt any needed action.

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During the debriefing, it was agreed that the alerting value of these indicators must be improved for CPDLC I. Suggested alternatives for improving the salience of these alerts in the status list included the use of color, reverse text, or possibly blinking of the status abbreviation. A brightness increase was judged to be a less desirable option because it would loose its distinctiveness when controllers select a high level of ambient brightness for the status list.

4.1.5 Transfer of Communication.

The controllers were generally satisfied with the available options for sending manual TC messages, modifying handoff commands to alter TC uplinks, and selectively overriding the TC mode.

The tested functionality provided for acquiring (stealing) Data Link eligibility from another sector required a second command to uplink the new sector's voice radio frequency to the aircraft. The group recommended that a combined command be made available for future evaluation.

The tested design provided an ability to release Data Link eligibility in order to compensate for controllers who choose not to use the CPDLC capability. In this design, the non-using controller must make inputs to pass eligibility to the next sector after completing the handoff and voice transfer of communication (RE FLID or *DL* FLID).

The group expressed concern that, for various reasons, the non-using controller may fail to carry out the release action. This would result in additional workload for the receiving controllers and potentially nullify any benefits that would otherwise be associated with their use of Data Link. For future CPDLC builds, it was recommended that efforts should be invested in designing support features that would ensure that non-using controllers would make the release entries. One of the controllers suggested that a list be built with the FLIDs of aircraft requiring Data Link eligibility release, and that the release command be accomplished by a trackball select of the list entry.

4.1.6 Menu Text.

The controllers did not identify any changes to the menu text functionality or HCI that will be required for fielding CPDLC I. However, three improvements for future system builds were recommended.

The controllers indicated that the *MT UP* should be an implied input when the trackball is used to select a menu text item and the aircraft's position symbol as a method for sending a message. Additionally, the controllers suggested that

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the MT list (as well as the status list) might be more effectively implemented as DSR views than as Host lists. This modification would make Data Link functionality consistent with the view-oriented DSR display conventions, and would provide the semi-opaque view display capability and the ease of interaction offered by DSR. Finally, the group agreed that an automation enhancement to the menu text functionality would be desirable in future builds. This enhancement would permit controllers to select a temporary MT message that would be automatically uplinked to every aircraft that made an initial contact with their sector. The addition of this feature would reduce the workload associated with sending every aircraft important, but repetitive information, required when specific conditions pertain in the sector (e.g., a temporary weather situation).

### 4.1.7 Additional Issues.

The controllers were asked several general questions both in the individual design review and during the group debriefing. The findings obtained from their responses are discussed in the following paragraphs.

### a. List Position Indicators

In a general evaluation of Data Link lists, the group noted that the position at which the status list will appear on the situation display should be indicated when no transactions are in progress and when the list is suppressed. Likewise, controllers should have an indication of the location of menu text list when it is suppressed.

### b. Transaction Delays

The controllers were asked whether they felt that the total transaction delays that they experienced during the Data Link DYSIM exercises were short enough to support effective use of CPDLC I in the field. None of the controllers felt that these delays that were derived from the CPDLC I specification were excessive, or that they would limit the use of the four initial services in the field. However, several of the controllers noted that these delays should be more thoroughly examined in future studies with more realistic air traffic scenarios.

### c. Training

The controllers were asked two questions regarding training requirements for CPDLC I. When asked whether the Data Link training that they received during the test was adequate for this initial evaluation, a majority indicated that their introduction was acceptable. However, all agreed that

additional hands-on practice with a fully functional system would be needed for future high fidelity simulation studies.

The controllers also were asked for an initial assessment of current operational training plans for CPDLC I. These plans call for a program consisting of a 1-hour overview lecture, 4 hours of CBI, a 2-hour procedures lecture, and 6 hours of DYSIM exercises. Three of the controllers indicated that this level of training probably would be appropriate. The remaining participants felt that they were unable to make a meaningful judgment at this time.

d. Radar Associate Position Functionality

The controllers unanimously agreed that enhanced DSR functionality would be needed for the D-side in future CPDLC builds. Specifically, the group argued that the D-side controller would find it difficult to monitor Data Link transactions using the status list provided at the R-side position. Likewise, it was suggested that the lack of category keys would place additional memory demands on the D-side controller. The group recommended that the D-side be provided with a status list. Where possible, the group also recommended that category key functionality be provided at the D-side, either through the addition of keyboard keys, or by including a category key pick area in the D-CRD.

## 4.2 DESIGNS FOR NEW CPDLC IA SERVICES.

### 4.2.1 Route Assignment.

The controllers were presented with a baseline design for the route assignment service in an introductory lecture, and were then given the opportunity to dynamically exercise the design in a DYSIM session. The baseline design made use of the existing Host inputs for route assignment. Inputs currently used to update the NAS for a route clearance are modified by the addition of an "S" at the end of the command to send the clearance via Data Link. The controllers indicated that the baseline design for the route assignment service was acceptable as demonstrated in the test bed. However, they also recommended that it should also be possible to send route assignments using the menu text functionality.

### 4.2.2 Altitude Request Downlinks.

In addition to the route assignment service, the controllers were presented a candidate design for processing and responding to altitude requests downlinked from the flight deck. In the baseline design, the presence of a pending downlink is signaled by replacing the Data Link symbol in the FDB with a down-arrow. To view the open downlinks from any aircraft, the controller enters "DW" FLID. A

list appears for the aircraft, which displays all outstanding downlinks, the time of receipt, and a suggested positive response (e.g., CTAM FL370). The controller can respond by typing "S" (Send), "U" (Unable), "Y" (Standby), or "D" (Delete message), selecting the message in the list with the trackball, and pressing ENTER. Pressing "S", "U", or "Y" creates an entry in the status list for the uplinked response and deletes the request from the downlink list. Pressing "D" removes the request from the list, and does not send an uplink message. The controller can also view outstanding requests from all aircraft in the sector by typing "DW" ENTER. Inputs identical to those described above can be used to formulate and send a response.

The controllers agreed upon a number of modifications to the baseline downlink HCI. The group noted that controllers must be given an indication of the position at which a downlink list will appear on the situation display prior to requesting the list.

In addition, they recommended that the format of items shown in the display be modified. Specifically, the aircraft's computer identification (CID) should be presented first as the item referent, and the time of receipt should be the last entry on the first line of each item. Multiple messages should be presented in chronological order of receipt, and when multiple messages from a single aircraft exist, the CID should be followed by an alphabetic suffix to uniquely identify the message.

The controllers also recommended that the time delay be minimized between an entry to send a response and the removal of the message from the downlink list/appearance in the status list.

Finally, the controllers unanimously agreed that the D position be given full and independent capabilities to process downlinks. That is, the D-side should have an ability to request a downlink list that is displayed in the D-CRD for any single aircraft or for all aircraft. D-side requests for a downlink list should not present a list on the R-side.

## 5. CONCLUSIONS AND RECOMMENDATIONS.

The primary results of this study constitute an initial evaluation of the air traffic controller's Human-Computer Interface (HCI) and functionality for the four services provided by Controller-Pilot Data Link Communications (CPDLC) Build I (CPDLC I). The study also generated initial requirements for the design of two additional services that will be provided by CPDLC Build IA (CPDLC IA). All assessments were based on structured observations made by eight air traffic controllers after exercising the services on the Display System Replacement (DSR) under dynamic simulation conditions.

## 5.1  CPDLC I.

The following recommendations are based on the results of the individual design reviews and group debriefing conducted during this study.  These recommendations are divided into two categories.  The first category identifies design modifications judged by the controller participants to be essential to the successful deployment of CPDLC I during the limited key site implementation. The second category of recommendations consists of design changes that, while not considered essential for CPDLC I, will be mandatory for inclusion in future system builds beginning with CPDLC IA.

### 5.1.1  Required Design Modifications for CPDLC I.

a.  Non-Normal Status Alerts

The alerting characteristics of non-normal message status indications in the status list must be improved.  When a message is in the NEG, UNA, FAI, ERR or TIM state, the status list entry should be emphasized in some manner to reliably alert the controller and prompt any needed action.  Recommended alternatives for testing include the use of color, reverse text, or blinking.

b.  Full Data Block Symbols

The symbol used to indicate Data Link eligibility should be changed from an hourglass to a filled diamond.  The symbol used to indicate an ongoing transfer of communication should be changed from a pound sign to a lightning bolt.

c.  Data Link Settings

The design of the controller interface used to modify Data Link settings must be improved to permit more efficient and accurate controller performance. As a minimum, the alternative design described and illustrated in section 4.1.2 of this report should be adopted for CPDLC I.

d.  Data Link Key Location

The *MT UP* and *TC UP* keys should be relocated to the far right of the 12-key hard function key pack.

## 5.1.2  Design Modifications That Can Be Deferred to CPDLC IA.

### a.  Data Link Settings

· The functionality provided to adjust Data Link settings should be further improved.  As a minimum, controllers should be provided with the ability to use the trackball and trackball keys to toggle among the options for each setting. Optimally, Data Link settings should be incorporated with the DSR DC view.

### b.  Implied Commands

The *TC UP* and *MT UP* commands should not be required when the controller uses the trackball to select held transfer of communication messages or menu text items and to designate the FLID.

### c.  Data Link Lists

The status list and menu text list should be converted to DSR views.

### d.  Releasing Data Link Eligibility

Support features should be developed to help ensure that a controller who is not using CPDLC will make the necessary inputs to release Data Link eligibility to the next sector for each equipped aircraft.

### e.  D-Side CPDLC Capabilities

The associate radar controller (D-Side) is expected to assume a major role in the use of Data Link.  For this reason, the D-side should be provided with enhanced CPDLC control and display capabilities.  Specifically, this control position should have a repeater of the status list and dedicated CPDLC keys on the keyboard and in a pick area on the D-CRD.

### f.  Data Link Symbols

The heights of the Data Link symbols in the FDB should be increased over those used in the present study to insure that they are discriminable when the controller selects small font sizes.

## 5.2  REQUIREMENTS FOR ROUTE ASSIGNMENT AND DOWNLINK SERVICES.

The controller participants recommended modifications to the baseline designs for the route assignment and downlink services.  These recommendations are

recorded in section 4.2 of this report. The modifications should be incorporated in the Data Link test bed and evaluated in future studies.

## 6.    REFERENCES.

Darby, E.R. Jr. *Design Review of the Controller-Pilot Data Link Communications Build I (CPDLC I) Functionality and Computer-Human Interface for the Display System Replacement (DSR).* Federal Aviation Administration, William J. Hughes Technical Center, Final Report, DOT/FAA/CT-98/16, August 1998.

Data Link Human Factors Working Group *Controller-Pilot Data Link Communications Roadmap for Human Factors Activities.* Federal Aviation Administration, 1998.

## 7.   ABBREVIATIONS AND ACRONYMS.

| | |
|---|---|
| ACARS | ARINC Communications Addressing and Reporting System |
| ARTCC | Air Route Traffic Control Center |
| AS | Altimeter Setting |
| ATC | Air Traffic Control |
| ATCS | Air Traffic Control Specialist |
| ATDLVT | Air Traffic Data Link Validation Team |
| ATN | Aeronautical Telecommunications Network |
| CBI | Computer-Based Instruction |
| CID | Computer Identification |
| CPDLC | Controller-Pilot Data Link Communications |
| DC | Display Control |
| DLAP | Data Link Applications Processor |
| DSR | Display System Replacement |
| DYSIM | Dynamic Simulation |
| FAA | Federal Aviation Administration |
| FDB | Full Data Block |
| HCI | Human Computer Interface |
| HCS | Host Computer System |
| IC | Initial Contact |
| MT | Menu Text |
| NATCA | National Air Traffic Controllers Association |
| OT | Operational Test |
| PVD | Plan View Display |
| R-CRD | Radar Computer Readout Device |

# APPENDIX A

## INDIVIDUAL'S CONSENT TO VOLUNTARY PARTICIPATION IN A RESEARCH PROJECT

# APPENDIX A

## INDIVIDUAL'S CONSENT TO VOLUNTARY PARTICIPATION IN A RESEARCH PROJECT

I _____ , understand that this study entitled "Controller Evaluation of Controller-Pilot Data Link Communication (CPDLC) Services implemented on the Display System Replacement (DSR) Workstation" is sponsored by the Federal Aviation Administration (FAA) and is being directed by the Data Link Branch (ACT-350) of the Communications, Surveillance and Navigation Division.

I have been recruited to volunteer as a participant in the project named above. The purpose of this project is to obtain expert controller input regarding the design of the inputs and displays that were used to provide a CPDLC capability on the DSR controller workstation.

### Nature and Purpose

The project will involve my participation over a period of 4 days. There will be approximately seven other en-route Air Traffic Control Specialists (ATCSs) participating with me. The project activities will take place during normal workdays with breaks for meals. I will be required to attend classroom training sessions and practice sessions in the air traffic control (ATC) simulation laboratories to acquaint me with Data Link and the DSR. I will then perform an individual evaluation of the CPDLC human-computer interface (HCI), and participate in a group debriefing. I will also participate in group discussions to generate candidate designs for additional services and to assess draft CPDLC procedures.

### Study Procedures

The study will begin with a classroom training session on the DSR HCI followed by the dynamic simulation (DYSIM) practice. Next, I will receive training on the CPDLC HCI followed by simulation exercises in the ATC simulation laboratory to familiarize me with the Data Link commands and displays as implemented on the plan view display (PVD). I will use these experiences as a basis for completing an individual design review of the proposed CPDLC HCI for DSR. The design review booklet will provide a description of each design feature and provide space for my comments and recommendations. The review will conclude with a structured group debriefing to identify individual areas of concern and to achieve consensus where possible.

Finally, I will participate in two organized discussion sessions to make recommendations for the design of two additional services and to evaluate draft procedures for the use of CPDLC in the field.

Discomfort and Risks

I understand that there are minimal physical or psychological risks associated with participation in this study. The simulation facilities use equipment and workstations that are identical to those currently used by en route controllers in Air Route Traffic Control Centers (ARTCCs). The tasks that I will perform in the laboratories will be the same, or similar, to those I perform in my job as an ATCS.

Precautions for Female Participants

The risks of participating in this study are substantially the same as those encountered by operational en route ATCSs performing their normal duties. If I am a female ATCS, I understand that I must exercise the same precautions that I would at my job to avoid risks to myself, the embryo or fetus if I currently am, or may become pregnant.

Benefits

I understand that the only direct benefit to me is that I will receive my normal FAA pay and travel reimbursement while participating in this study.

Participant Responsibilities

I understand that by volunteering for this study that I accept the obligation to make an honest evaluation of the CPDLC HCI for DSR based on my past experience as an en route ATCS and on the information and simulation experiences that are provided to me during this study.

Compensation and Injury

I agree to report any personal injury or suspected adverse effect of this study to Mr. Darby at 609-485-6345. I understand that, as an official government employee duty, accident insurance coverage for this study activity is provided by the Workmen's Compensation Insurance Fund in relation to my Federal Government employment.

## Participant's Assurances

I understand that my participation in this study is completely voluntary. I am participating because I want to. Mr. Darby has adequately answered any and all questions that I have about this study, my participation, and the procedures involved. I understand that Mr. Darby will be available to answer questions concerning procedures throughout this study.

I have not given up any of my legal rights or released any individual or institution from liability for negligence.

I understand that records of this study will be kept confidential, and that I will not be identifiable by name or description in reports or publications about this study.

I understand that I may withdraw from this study at any time without penalty or loss of benefits to which I am otherwise entitled.

If I have questions about this study or need to report adverse effects from the study activities, I will contact Mr. Darby at 609-485-6345 during the workday or 1-800-832-2506 at other times.

I have read this consent document. I understand its contents, and I freely consent to participate in this study under the conditions described. I have received a copy of this consent form.


Study Participant: _____ Date: _____

Investigator: _____ Date: _____

Witness: _____ Date: _____

# APPENDIX B

# CONTROLLER EVALUATION MATERIALS

## DISPLAY SYSTEM REPLACEMENT (DSR)
## CPDLC I HUMAN-COMPUTER INTERFACE

## CONTROLLER DESIGN REVIEW BOOKLET

This booklet contains a series of questions that will permit you to independently review and evaluate the CPDLC I Human-Computer Interface (HCI) that will be implemented on the DSR. The goals of this review are to identify those aspects of the HCI that will be acceptable as presented, or will require modification prior to fielding.

Please answer all of the questions in this booklet and carefully record your comments and any recommendations for design changes. Please explain your reasons for suggesting any changes.

Reviewer's Name   _____

Instructions

This booklet is divided into six parts that will permit you to make a detailed evaluation of the functionality provided by CPDLC I and the controller interface design. Each part begins with a design description. Read these descriptions carefully before answering the associated questions and recording your comments.

NOTES ON CONVENTIONS USED IN THE DESIGN DESCRIPTIONS

- Data <u>as shown in a display or entered on the keyboard</u> are presented in quotation marks. When spaces are required, they are included within the quotation marks. The quotation marks are not part of the display or entry.

- All spaces included within quotation marks for keyboard entries are mandatory. For example, "MT ON" should be interpreted as typing MT, a space, and ON.

- Input commands printed in bold italics refer to a DSR keyboard category, soft function, or hard function key, or a "key" in the R-CRD Category Selection Area (e.g. *DL, DS, FI*).

- Two trackball keys are used. Trackball ENTER (middle key) is used to complete a command sequence. Trackball SELECT (left key) is used to identify an item in the R-CRD text area or the status list and to identify lists for moving them on the display.

- FLID refers to any NAS command for identifying a flight including:

       . The Aircraft Identification Call Sign (AID)

       . The Computer Identification Number (CID)

       . The Beacon Code

       . Positioning the trackball cursor over the data block and pressing trackball ENTER

All keyboard entries must be followed by a keyboard ENTER or a trackball ENTER to complete the command sequence.

Data Link Keys

The CPDLC I HCI for DSR uses three dedicated keyboard keys and two "pick" keys in the R-CRD category selection area. The Data Link (*DL*) keyboard and pick keys are used to send some messages, delete messages, transfer eligibility, and initiate or terminate a Data Link session with an aircraft. The Data Link Settings (*DS*) pick key is used to set the Transfer of Communications mode, display and modify a list of current sector Data Link settings, and to select or modify the contents of Data Link lists. The two remaining keyboard keys are used to uplink a transfer of communication message in the "held" status (*TC UP*), and to send a message contained in the menu text list (*MT UP*).

The current locations for these keys and the function key menu that is presented in the R-CRD category selection area when the *DL* or *DS* keys are pressed are shown in the following diagrams:
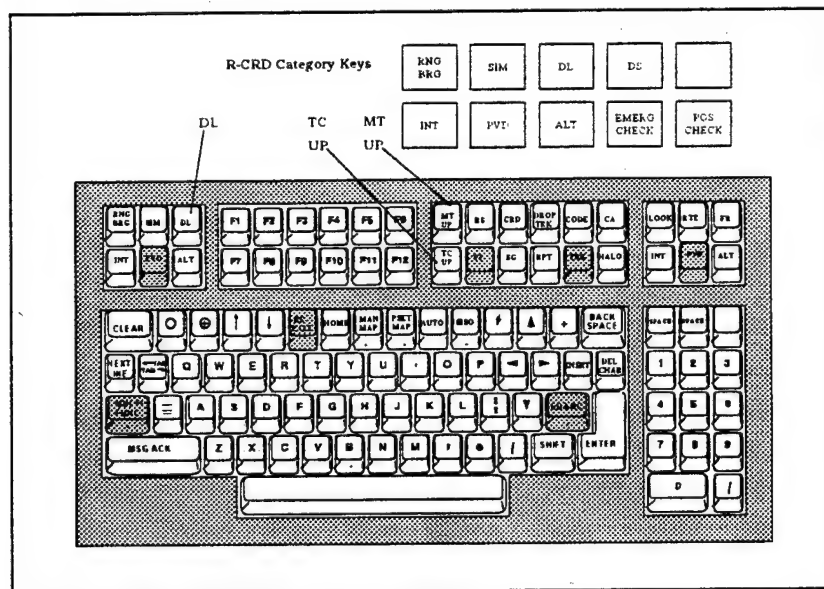
DL category menu:

| RELEASE ELIGIBILITY | RL | F1 |
|---|---|---|
| UPLINK FREQUENCY | UF | F2 |
| ACQUIRE ELIGIBILITY | AL | F3 |
| | | |
| END SESSION | ED | F4 |
| DELETE MESSAGE | DE | F6 |
| START SESSION | SD | F7 |
| | | |
| DYSIM RESPONSE | JU | F9 |
| DYSIM MENU | JN | F10 |

RELEASE ELIGIBILITY:  Sends eligibility to another sector that has track control  (NOTE: two-letter command in the Test Bed is RE)
UPLINK FREQUENCY: Sends your frequency to an aircraft
ACQUIRE ELIGIBILITY: Transfers eligibility to your sector if you have track control  (NOTE: two-letter command in Test Bed is SX)
END SESSION: Manually terminates a data link session with an aircraft
DELETE MESSAGE: Deletes a transaction shown in the status list
START SESSION: Manually initiates a data link session with an aircraft
DYSIM RESPONSE: Training function
DYSIM MENU: Training function

DS category menu:

| TOC MODE | AT | F1 |
|---|---|---|
| SECTOR DL | XX | F2 |
| | | |
| MENU TEXT LIST | MT | F3 |
| SUPP/RECALL MT | MS | F4 |
| | | |
| SECTOR SETTINGS | SN | F7 |
| SL SERVICES | SV | F8 |
| STATUS LIST | SL | F9 |
| SL STATES | SZ | F10 |

TOC MODE: Used to set TOC to AUTO or MANUAL
SECTOR DL: Turns Data Link off or on at sector
MENU TEXT LIST: Permits suppression or recall of entire MT list
SUPP/RECALL MT: Permits suppression or recall of individual permanent items in the MT list

SECTOR SETTINGS: Displays all current settings for functions in the DS
category menu for X seconds. These can be modified while the list is displayed
by using the alternative two-letter inputs for invoking the functions.
SL SERVICES: Permits filtering the contents of the SL by service type
STATUS LIST: Permits suppressing/retrieving the entire status list
SL STATES: Permits filtering the contents of the SL by transaction status

CPDLC I Key Evaluation
Questions:

1. Are the locations of the Data Link keys on the keyboard (*DL, MT UP,
   TC UP*) and in the R-CRD "pick" area (*DL, DS*) acceptable for the
   functions that they serve?

2. Are the abbreviations used to label the Data Link keys meaningful
   and not susceptible to confusion with other key designations used in
   DSR?

3. Are the Data Link functions appropriately grouped under the *DL* and
   *DS* keys?

4. Are the items shown on the R-CRD when the *DL* and *DS* keys are
   pressed unambiguous and do they adequately indicate the functions
   that they will perform?

5. If the Data Link keys (*DL, DS, TC UP, MT UP*) were not available, would it be acceptable to perform these functions using the alternative two-letter Host commands only?

6. Are "RELEASE ELIGIBILITY" and "TOC MODE" appropriate choices for the "hot" key under the *DL* and *DS* keys?

Overall Rating of Data Link keys:

_____    THE DESIGN AS DESCRIBED HERE IS ACCEPTABLE – NO CHANGES ARE DESIRABLE OR NEEDED

_____    THE DESIGN AS DESCRIBED HERE IS ACCEPTABLE – NO CHANGES ARE NEEDED <u>BUT</u> THE FOLLOWING MODIFICATIONS OR IMPROVEMENTS WOULD BE DESIRABLE:

_____    THE DESIGN AS DESCRIBED HERE IS UNACCEPTABLE— THE FOLLOWING CHANGES <u>MUST</u> BE MADE:

Part II

Status List and Full Data Block

- Function

The Full Data Block (FDB) provides unique graphic characters which indicate that an aircraft is equipped to receive Data Link messages and has an active Data Link session, and whether the observing control position is eligible to uplink messages to the aircraft. The FDB also provides limited information about the status of ongoing Data Link transaction.

The status list is a Host situation display tabular list that contains full information about the content and current status of ongoing Data Link transactions. The status list does not appear on the D position display.

- Full Data Block Equipage and Eligibility Indicators

Data Link equipage/session and eligibility are indicated by graphic characters located in the first position of the first line of the FDB. No special character in this position identifies an aircraft that is not capable of communicating via Data Link or does not have an active Data Link session. An open diamond (◊) indicates that the aircraft is Data Link equipped and has an active session, but that the viewing sector position is ineligible to communicate with it. An "hour glass" ( ) indicates that the aircraft is equipped with ⧖ an active session, and that the viewing sector is eligible.

Data Link sessions with aircraft are normally established and terminated by automation. The controller can manually establish an active session with an aircraft that has logged-on to the Data Link system by entering *DL F7*, or typing "SD", followed by the FLID. A session can be terminated by entering *DL F4*, or typing "ED", followed by the FLID.

- Status List Format

The status list is identified by "SL" displayed in the header area of the list. Each line of the list contains information about one ongoing transaction. A line has three data fields displaying (1) the aircraft identification, (2) an abbreviated version of the content of the uplinked message, and (3) and an indication of the current status of the transaction. For example:
"UAL172  123.125  SNT" would indicate that the controller had uplinked a message to switch radio frequencies to UAL 172 and that the message is in the sent status.

- Status List Abbreviations of Transaction Status

The third field of a status line presents the following abbreviations to indicate the current status of the transaction:

"SNT" - Sent:  A controller input or system event has initiated the uplink

"HLD" - Held:  A transfer of communication message containing the radio frequency of a new airspace sector, which the aircraft will enter, has been prepared and is ready for uplink when the sending controller makes an appropriate input.

"ROG" - Roger
"AFF" - Affirmative
"WIL" - Wilco:  The system has received a downlink from the flight deck indicating that the pilot has received the message / agrees with / or will comply with the uplinked message.

"NEG" - Negative
"UNA" - Unable:  The system has received a downlink from the flight deck indicating that the pilot has received the uplinked message, but does not agree with / is unable to comply.

"SBY" - Standby: The system has received a downlink from the flight deck indicating that that the pilot has received the uplinked message and will subsequently reply with a positive or negative response.

"TIM" - Time Out:  A timer initiated when the uplinked message was sent has expired.  This is an adaptable time parameter nominally set at 40 seconds.  The time out status is an indication to the controller of an unusually lengthy delay for receipt of a response from the aircraft. The transaction remains open, and a subsequent response  will be accepted by the system.

"FAI" - Failed:  Indicates that the Data Link session with the intended receiving aircraft has been aborted.  The transaction is closed.

"ERR" - Error:  Indicates that an application error has occurred in attempting to send the message.  If the data field of the status list entry indicates "local error" the message has not been received by the pilot.  If any other message appears in the data field, the message may, or may not, have been received by the pilot.  The ERR status closes the transaction and prevents a pilot response.

All states that close a transaction with a positive response (ROG, WIL, AFF) will delete the relevant line on the status list after an adjustable time parameter (nominally 6 seconds) has expired.  Messages in any other transaction state must be manually deleted using inputs described in succeeding sections of this booklet.

- Full Data Block Indications for CPDLC I Services and Status

FDB indicators are correlated with the status list indicators, but vary depending upon the service involved.  They are described in detail under succeeding sections devoted to each service.

- Inputs to Move the Status List

The status list can be moved to any position on the situation display by pressing *PVD* "L", slewing to the desired position, and pressing the trackball ENTER key.

- Inputs to Suppress or Retrieve the Status List

The status list can be suppressed by typing *DS F9* "OFF" or "SL OFF".  The list is retrieved to the situation display by typing *DS F9* "ON" or "SL ON."  These entries cannot be made from the D position.

- Selecting Message Types for Display in the Status List

The status list will display information on all four types of messages included in CPDLC I.  However, the Radar controller can selectively suppress status list content by message category.  The following table presents the commands used to selectively suppress and retrieve each message type.

|  | Category Key Command | Two-letter Command |
|---|---|---|
| Transfer of Communication | *DS F8* "TC OFF" or "TC ON" | "SV TC OFF" or "SV TC ON" |
| Menu Text | *DS F8* "MT OFF" or "MT ON" | "SV MT OFF" or "SV MT ON" |
| Altimeter Setting | *DS F8* "AS OFF" or "AS ON" | "SV AS OFF" or "SV AS ON" |
| All Message Types | *DS F8* "OFF" or "ON" | "SV OFF" or "SV ON" |

It is also possible to display or suppress multiple message types in a single command (e.g., *DS F8* "TC MT OFF")

Note that any transaction that results in a negative response or a TIM will be automatically forced to appear in the status list even if that message type is suppressed.

- Selecting Message States for Display in the Status List

The Radar controller also can determine the messages that will appear in the status list by their respective states. The following table presents the commands used to selectively suppress and retrieve the display of messages in five states. Messages with any other status cannot be suppressed.

|  | Category Key Command | Two-letter Command |
|---|---|---|
| SENT | *DS F10* "SNT OFF" or "SNT ON" | "SZ SNT OFF" or "SZ SNT ON" |
| ROGER | *DS F10* "ROG OFF" or "ROG ON" | "SZ ROG OFF" or "SZ ROG ON" |
| WILCO | *DS F10* "WIL OFF" or "WIL ON" | "SZ WIL OFF" or "SZ WIL ON" |
| AFFIRMATIVE | *DS F10* "AFF OFF" or "AFF ON" | "SZ AFF OFF" or "SZ AFF ON" |

Full Data Block and Status List Evaluation

Do the Full Data Block symbols provide unambiguous information regarding Data Link equipage/active session and eligibility?

Are the transaction status abbreviations used in the status list sufficiently clear and easy to understand?

Are the "abnormal" status indications (NEG, UNA, FAI, ERR, TIM) sufficiently obvious to alert the controller and prompt any needed action?

Does the design provide an adequate capability to control (filter) the contents of the status list (i.e., by message type and status)?

When a D position controller is involved in sending Data Link messages, will the status list displayed on the R-side situation display be adequate for monitoring Data Link transactions?

Overall Rating of Full Data Block and Status List Displays/Inputs:

_____ THE DESIGN AS DESCRIBED HERE IS ACCEPTABLE –
NO CHANGES ARE DESIRABLE OR NEEDED.


_____ THE DESIGN AS DESCRIBED HERE IS ACCEPTABLE –
NO CHANGES ARE NEEDED BUT THE FOLLOWING
MODIFICATIONS OR IMPROVEMENTS WOULD BE
DESIRABLE:


_____ THE DESIGN AS DESCRIBED HERE IS UNACCEPTABLE—
THE FOLLOWING CHANGES MUST BE MADE:

Transfer of Communication (TOC)

- Function

The Data Link transfer of communication message is automatically prepared when the receiving controller accepts a sector handoff for an equipped aircraft. The sending controller has the option to send the new frequency automatically when the handoff is accepted, or to send the message manually at a later time.

- Inputs to Set the Transfer of Communication Mode

Transfer of communication can be set to the automatic mode by typing *DS F1* "AUTO" or "AT AUTO". The manual mode is selected by typing *DS F1* "MAN" or "AT MAN". Note that, as the default function, *F1* may be omitted from the command sequence.

The selected mode for TOC is shown in a banner on the situation display.

- Automatic and Manual Send Inputs

When in the automatic mode, the transfer of communication message will uplink the default frequency for the receiving sector with no additional action by the sending controller when the receiving sector accepts the handoff.

When in the manual mode, acceptance of the handoff will store the message for later transmission. The message will appear in the status list in the "HLD" status. The controller can send the message by a trackball slew/ENTER to the "dot" preceding the appropriate line in the status list or by pressing the *TC UP* key followed by the FLID, or by typing "UH" followed by the FLID.

- Changing the Default Frequency

Frequencies other than the primary default frequency for the receiving sector can be sent when using CPDLC for the transfer of communication. When making the entries to handoff the aircraft, typing "U" after the sector number will substitute a predefined alternate frequency (e.g., "22 U TWA254"). Typing a numeric radio frequency value in the same position will send that frequency, if adapted, for the facility.

- Status List and Full Data Block Displays on Transfer of Communication

The status list entry for a transfer of communication transaction presents the AID, the uplinked frequency, and the current transaction status message. When in a manual mode, the "HLD" status message is displayed until the controller completes the slew action or keyboard to send the message. In the automatic mode, the status line appears in the "SNT" state immediately after acceptance of the handoff.

In either mode of operation, when the transfer of communication message is sent, a "pound" symbol (#) replaces the Data Link equipage/eligibility indicator in the first position of the first line of the Full Data Block. This symbol will appear at all sectors displaying the aircraft's full data block. When the wilco is received from the flight deck, the pound symbol is replaced by the hourglass in the receiving sector and by the open diamond in all other sectors.

In an interfacility transfer of communication, the receiving sector will display the hourglass and all Data Link eligibility symbology will be removed from sectors in the sending facility.

- Unable and Time Out Displays for Transfer of Communication
  and Controller Responses.

If the flight deck responds to a transfer of communication message with an unable, "UNA" is displayed in the status field of the status list. If the flight deck fails to downlink a response within 40 seconds (adaptable), "TIM" is displayed in the status field.

The unable conditions also will cause the pound symbol in the first position of the first line of the sending controller's Full Data Block to revert to the hourglass symbol indicating that Data Link eligibility remains at the sending sector. All other sectors will display the open diamond.

- Deleting Transfer of Communication Transactions

The controller can close the transaction and delete "HLD", "UNA", "ERR", or "FAI" indicators by typing *DL F6* "TC" and the FLID or "DE TC" and the FLID. If the controller chooses to delete a transaction in the "SNT", "SBY" or "TIM" states "/OK" must be included in the command sequence prior to "TC" (e.g., *DL F3* "/OK TC USA219").

A transaction can also be deleted by eliminating "TC" in the command and using the trackball to select the dot preceding the appropriate line in the status list.

- Sending an Automatic Transfer of Communication When in Manual
  Mode

While working in the manual mode, the controller can selectively choose to send
the message automatically to an individual aircraft by adding a single keystroke
to the normal sequence used to offer a handoff.

The transfer of communication message will be sent automatically upon handoff
acceptance if the controller offers the handoff by typing the two-digit receiving
sector number, " S", and the FLID (e.g., "22 S USA435"). Alternate frequency
options may be included in the command. Only one aircraft may be designated
in the message. Adding the " S" to a single handoff command will not affect
other subsequent aircraft handoffs, and the selected mode will remain manual.

- Holding a Transfer of Communication When in Automatic

While working in the automatic mode, the controller can selectively choose to
hold the message for an individual aircraft by adding a single keystroke to the
normal sequence used to offer a handoff.

The transfer of communication message will be put into the held status upon
handoff acceptance if the controller offers the handoff by typing the two-digit
receiving sector number, " I", and the FLID (e.g., "22 I USA435"). Alternate
frequency options may be included in the command. Only one aircraft may be
designated in the message. Adding the "I" to a single handoff command will not
affect other subsequent aircraft handoffs, and the selected mode will remain
automatic.

- Acquiring Data Link Eligibility Without a Handoff

If a controller has track control for an aircraft, Data Link eligibility can be
acquired from another sector in the absence of a completed handoff by typing
*DL F3* or "AL", followed by the FLID. This action does not uplink the acquiring
sector's radio frequency to the aircraft. (NOTE: two-letter command in Test Bed
is "SX" -- change to "AL" is pending)
Track control and Data Link eligibility can be acquired from another sector in
the absence of a handoff with a single input by typing "/OK D" and the FLID.

- Sending a Radio Frequency to an Aircraft Without a Handoff

A controller who has acquired Data Link eligibility in the absence of a handoff
can send his/her sector's radio frequency to the aircraft by typing *DL F2* or "UF",
followed by the FLID.

Frequencies other than the primary default frequency for the sector can be substituted. Typing "UF U" or *DL F2* "U", followed by the FLID will substitute a predefined alternate frequency. Typing a numeric radio frequency value, rather than "U", will send that frequency if adapted for the facility.

When a frequency is sent in this manner, the message will instruct the pilot to "monitor" the new frequency. If "C" is inserted, the message will instruct the pilot to "contact" the controller on the new frequency (e.g., "UF C NWA899").

- Initiating a Handoff Without Preparing a Transfer of Communication Message

An aircraft with an ongoing Data Link session can be handed off without preparing or sending a transfer of communication message by typing the receiving sector's number, "O" and the FLID (e.g., "22 O USA219").

- Forwarding Data Link Eligibility when CPDLC Transfer of Communication is Off

A controller who has turned Data Link off at his sector, or who elects not to use Data Link to accomplish the transfer of communications, must forward eligibility to the next sector. After handing off an aircraft and instructing the aircrew to contact the next sector via voice radio, the controller will forward eligibility to the sector with track control by typing *DL F1* or "RL", followed by the FLID. (NOTE: two-letter command in Test Bed is "RE" -- change to "RL" is pending)

Transfer of Communication

Evaluation

Questions:

1. Are the available input options for sending a "held" transfer of communication message adequate for the R controller? D controller?

2. Are the Full Data Block indicators along with the status list adequate for monitoring an ongoing transfer of communication transaction?

3. Are the inputs for temporarily changing the transfer of communication mode (auto/manual) for a single aircraft acceptable?

4. Are the inputs used to "steal" Data Link eligibility acceptable?

5. Are the inputs used to send a voice radio frequency in the absence of a handoff acceptable?

6. Will the options to substitute an alternate frequency in the handoff message ("U", typed frequency) and to inhibit the preparation of a TOC message ("O") adequately support the controller's operational requirements?

7. Are the inputs required for releasing eligibility when a controller has Data Link "off" at the sector acceptable ?


Overall Rating of Transfer of Communication Displays/Inputs:

_____  THE DESIGN AS DESCRIBED HERE IS ACCEPTABLE – NO CHANGES ARE DESIRABLE OR NEEDED.


_____  THE DESIGN AS DESCRIBED HERE IS ACCEPTABLE – NO CHANGES ARE NEEDED BUT THE FOLLOWING MODIFICATIONS OR IMPROVEMENTS WOULD BE DESIRABLE:


_____  THE DESIGN AS DESCRIBED HERE IS UNACCEPTABLE— THE FOLLOWING CHANGES MUST BE MADE:

Part IV

## Initial Contact (IC)

- Function

This service substitutes the initial radio call from the flight deck after a transfer of communication with a downlink report of assigned altitude. Under normal conditions, the initial contact procedure is automatic and transparent, and requires no controller interaction.

- Initial Contact Procedure

An assigned altitude request message is automatically appended to the radio frequency assignment message that is uplinked during transfer of communication. The flight deck responds to the transfer of communication uplink by downlinking a wilco along with a report of assigned altitude to the receiving controller.

Receipt of the wilco response transfers Data Link eligibility to the receiving sector. In addition, the reported assigned altitude is automatically checked against the aircraft's assigned altitude, interim altitude, or adapted altitude recorded in the NAS database. If the aircraft's reported downlinked assigned altitude matches the database value, nothing is displayed at the sending or receiving sectors, and no additional controller action is required.

Note that the transfer of communication message will normally instruct the pilot to "monitor" the new frequency. If the new sector is not equipped for Data Link, it will instruct the pilot to "contact" the controller at the new frequency and no altitude request will be sent.

- Discrepancy Between Reported and Assigned Altitudes

If the reported assigned altitude fails to match the assigned or interim altitude contained in the NAS database, the downlinked value followed by "I" will appear in the first four positions of the second line of the Full Data Block. This will timeshare every 1.5 seconds with the database value followed by the altitude conformance indicator. If the Mode C altitude had been displayed in this field when the timesharing began, the Mode C altitude will be shifted to the right of the second line to make it continuously viewable.

In addition to the FDB display, a status list entry will be created displaying the AID, the NAS data base altitude, and the downlinked altitude. The downlinked

altitude will be right justified in the data field of the status list. The status field will show "/IIC"
(e.g., TWA515   240            340/IIC").

The Data Link eligible receiving controller with track control can resolve the mismatch by contacting the flight deck via voice radio. The error displays may be cleared by deleting the IC status list entry (*DL F6* "IC" and the FLID or "DE IC" and the FLID).

Initial Contact

Evaluation

Questions:

1. Are the timeshared FDB display and the status list indicator sufficient to alert the controller of an initial contact downlink of an altitude that fails to match the NAS database?

2. Are the options for deleting an IC mismatch acceptable?

<u>Overall Rating of Initial Contact Displays/Inputs:</u>

_____   THE DESIGN AS DESCRIBED HERE IS ACCEPTABLE –
NO CHANGES ARE DESIRABLE OR NEEDED.


_____   THE DESIGN AS DESCRIBED HERE IS ACCEPTABLE –
NO CHANGES ARE NEEDED <u>BUT</u> THE FOLLOWING
MODIFICATIONS OR IMPROVEMENTS WOULD BE
DESIRABLE:


_____   THE DESIGN AS DESCRIBED HERE IS UNACCEPTABLE—
THE FOLLOWING CHANGES <u>MUST</u> BE MADE:

Menu Text

- Function

The Menu Text function permits the controller to uplink nonsafety critical messages by selecting them from a predefined menu list. Menus can be tailored to meet the specific requirements of individual airspace sectors.

- Menu Format

The menu is a Host situation display tabular list identified by "ML" in the header area of the list. Each line of the menu contains one message preceded by an identifying menu referent used to select the message. The menu referent must begin with an alphabetic character. Up to 10 messages can be displayed in the menu list. A sample menu is shown below:

```
. A        WRI ILS OUT RWY 6 / 24
. B        BAD WEATHER WARN
. MIC       CHECK STUCK MIC
. CALL      CALL COMPANY
```

- Inputs to Send a Menu Text Message

To send a menu text message, press the *MT UP* key (or type "UM"), the menu item referent, and the FLID (e.g., *MT UP* "A USA456"). The menu item referent can be typed or selected by a trackball slew to the dot preceding the message in the list.

The message can be sent to all aircraft that are Data Link eligible for the sector by substituting " *ALL " for the FLID.

- Full Data Block and Status List Displays on Menu Text Uplink

When a menu text message is uplinked, an up-arrow ( ) symbol replaces the hourglass in the first position of the first line of the Full Data Block at all positions displaying the Full Data Block. The up-arrow is removed when the message receives the appropriate positive or negative response from the flight deck or when it is deleted from the status list.

For all messages sent from the menu, the status list will display the AID followed by the menu item referent, and the current status of the transaction (e.g., "AA231 CALL  SNT"). The status list line is deleted when the appropriate positive or

negative response from the flight deck is received, or when it is deleted from the status list.

When a message is sent to all aircraft, a single line is created in the status list with "ALL" appearing the FLID field. The status line is deleted when all of the aircraft respond with the appropriate positive response. A separate line is created in the status list for each negative aircraft response to an all message, or if a transmission error occurs ("ERR", "FAI").

- Deleting Menu Text Transactions

The controller can close the transaction and delete "UNA","ERR", "FAI", or "NEG" indicators by typing *DL F6* "MT" and the FLID or "DE MT" and the FLID. If the controller chooses to delete a transaction in the "SND", "SBY" or "TIM" states, "/OK" must be included in the command sequence prior to "MT" (e.g., *DL F6* "MT /OK USA219"). The transaction can also be deleted by eliminating the "MT" and FLID in the command and using the trackball to select the dot preceding the appropriate line in the status list. If the trackball is not used for this command, all MT transactions for the aircraft that are displayed in the status list will be deleted.

- Controlling Menu Text List Content

A menu build function will be used by supervisory personnel to create sector-tailored menus. However, the controller will have the capability to determine whether the menu list will be displayed, and to selectively display or suppress individual items. Messages continue to be available for uplink when suppressed from the display.

The menu list can be suppressed by typing *DS F3* "OFF" (or "MT OFF"). The list is retrieved to the situation display by typing *DS F3* "ON" or ("MT ON"). These entries cannot be made from the D position.

Suppression of the individual messages in the menu is accomplished by typing *DS F4*, the menu item referent, and "OFF" or "MS", the menu referent, and "OFF". A message can be retrieved by substituting "ON" in the command sequence.

Up to five messages can be suppressed or retrieved in a single command by separating the menu referents with spaces.

It should be noted that sectors may be assigned two types of menu messages. Permanent messages intended for routine use on a daily basis may be

suppressed from the list.  The system will not permit suppression of temporary messages created for nonroutine special situations.

- Inputs to Move the Menu

The menu text list can be moved to any position on the situation display by pressing *PVD* "A", slewing to the desired position, and pressing the trackball ENTER key.

Menu Text

Evaluation

Questions:

1. Are the available input options for sending a menu text message adequate for the R controller?  D controller?

2. Are the FDB indicators along with the status list adequate for monitoring an ongoing menu text transaction?

3. Are the options for suppressing/retrieving items in the menu text list acceptable?

## Overall Rating of Menu Text Displays/Inputs:

_____    THE DESIGN AS DESCRIBED HERE IS ACCEPTABLE –
NO CHANGES ARE DESIRABLE OR NEEDED.


_____    THE DESIGN AS DESCRIBED HERE IS ACCEPTABLE –
NO CHANGES ARE NEEDED BUT THE FOLLOWING
MODIFICATIONS OR IMPROVEMENTS WOULD BE
DESIRABLE:


_____    THE DESIGN AS DESCRIBED HERE IS UNACCEPTABLE—
THE FOLLOWING CHANGES MUST BE MADE:

Altimeter Setting (AS)

- Function

This Data Link message uplinks an altimeter setting to the flight deck. Normally, the uplink will be accomplished automatically in accordance with procedures and directives. An altimeter setting can also be manually uplinked by the controller.

- Manual Uplink of Altimeter Setting

An altimeter setting can be manually uplinked by pressing *CRD,* typing the designator for the station providing the local altimeter setting, "S" and the FLID.

- Full Data Block and Status List Displays for Altimeter Setting Messages

When an altimeter setting message is uplinked either automatically or manually, an up-arrow( ☐☐☐) symbol replaces the hourglass in the first position of the first line of the Full Data Block at all positions displaying the FDB. The up-arrow is removed when the message receives a "ROG" or "UNA", or is deleted from the status list.

For all altimeter messages, the status list will display the AID followed by the station designator and the altimeter setting, and the current status of the transaction (e.g., "AAL231  DCA 2997  SNT"). The status list line is deleted when a "ROG" is received. Messages in any other transaction state must be manually deleted.

- Deleting Altimeter Setting Transactions

The controller can close the transaction and delete "UNA" or "ERR" indicators by typing *DL F6* "AS" and the FLID or "DE AS" and the FLID. If the controller chooses to delete a transaction in the "SND", "SBY" or "TIM" state "/OK" must be included in the command sequence prior to "AS" (e.g., *DL F6* "/OK AS USA219"). The transaction can also be deleted by eliminating the "AS" and FLID in the command and using the trackball to select the line in the status list. If the trackball is not used for this command, all AS transactions for the aircraft that are displayed in the status list will be deleted.

Altimeter Setting
Evaluation

Are the inputs for sending an altimeter setting message adequate for the R controller?  D controller?

Are the Full Data Block indicators along with the status list adequate for monitoring an ongoing altimeter setting transaction?

Overall Rating of Altimeter Setting Displays/Inputs:

_____  THE DESIGN AS DESCRIBED HERE IS ACCEPTABLE – NO CHANGES ARE DESIRABLE OR NEEDED.

_____  THE DESIGN AS DESCRIBED HERE IS ACCEPTABLE – NO CHANGES ARE NEEDED BUT THE FOLLOWING MODIFICATIONS OR IMPROVEMENTS WOULD BE DESIRABLE:

_____  THE DESIGN AS DESCRIBED HERE IS UNACCEPTABLE— THE FOLLOWING CHANGES MUST BE MADE:

GENERAL QUESTIONS:

1. Are the inputs and displays for accomplishing functions under the Data Link Settings menu acceptable for managing the contents of the Menu Text List? Status List?

2. Do you feel that the Data Link turn around times (elapsed time from sending a message to receiving a pilot response) that you experienced in the simulations are short enough to enable effective use of CPDLC I by controllers in the field?

3. Earlier CPDLC studies indicated that controllers would prefer the the Full Data Block indicators for equipage and eligibility be changed from the open diamond and "hourglass" to an open diamond (active session but not eligible) and a filled diamond (active session and eligible). Please indicate your preferences below by placing a check mark in the appropriate column for each symbol set:

| | Best Option | Acceptable Option | Unacceptable Option |
|---|---|---|---|
| Open Diamond / Hourglass | | | |
| Open Diamond / Filled Diamond | | | |

4. The current Full Data Block indication for an ongoing transfer of communications is the pound symbol. A currently available alternative is a lightning bolt. Please indicate your preferences below by placing a

check mark in the appropriate column for each symbol set:

| | Best Option | Acceptable Option | Unacceptable Option |
|---|---|---|---|
| Pound Symbol | | | |
| Lightning Bolt | | | |

5. In future builds, would a "repeater" of the Status List at the DSR D position display be desirable?

6. In future builds, do you feel that it will be useful to take advantage of the DSR's color capability to emphasize important information and warnings (e.g., color coding of unable responses, failures, and timeouts in the Status List)?

7. Do you feel that the training and DYSIM exercises on DSR and Data Link that you received for this study provided you with an adequate basis for evaluating CPDLC I?

8. Based on your experience in learning CPDLC I for this study, do you feel that a training program consisting of a 1-hour overview lecture, 4 hours of Computer-Based Instruction (CBI), a 2-hour procedure lecture, and 6 hours of DYSIM exercises will be adequate for training controllers in the field?

9. In the current design, the D-Side keyboard does not include the *DL* and *DS* keys. Where accessible to the D-Side, the functionality provided under these keys must be accessed using two-letter commands. In a future build, do you feel that it would be useful to provide these keys on the D-Side keyboard or in a category "pick" area on the D-CRD ?